Forecasting a Better Future

Numerical Air Quality Prediction (NAQP) for the Northeast US during ICARTT-2K4: MAQSIP-RT Results in Context

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Acknowledgements

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Outline

- **Introduction and Background**
- **Description of ICARTT-2K4 and its Modeling Study**
- **MAQSIP-RT Results in Context of Seven Member Ensemble**
- **Study Conclusions: Individual Models and Ensembles**
- **Baron Advanced, Where are we going?**

Introduction and Background 1

Numerical Air Quality Prediction (NAQP)

- **NWP model(s)**
- **Anthropogenic and Biogenic Emissions Model(s)**
- **Photochemical/Particulate Atmospheric Chemistry Model(s)**
- **Data Ingest**
- **Model Output**
- **Product Dissemination within operational forecasting deadlines**

Introduction and Background 2

Numerical Air Quality Prediction (NAQP) Example Modeling Systems

NAQP Modeling System	Operational (Since)	Research
MAQSIP-RT	x (2000)	
ETA-CMAQ	x (2004)	
WRF-Chem		x (2002)
CHRONOS	x (1999)	

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Introduction and Background 3

BAMS Component Models and DataFlows

Met Data Ingest → **MM5V3.4 (NC WxScope)**

MM5V3.4 (NC WxScope) → **SMOKE Emissions Processing and Modeling System**

MM5V3.4 (NC WxScope) and **SMOKE Emissions Processing and Modeling System** → **MAQSIP-RT Photochemical Model**

MAQSIP-RT Photochemical Model → **Guidance Products**

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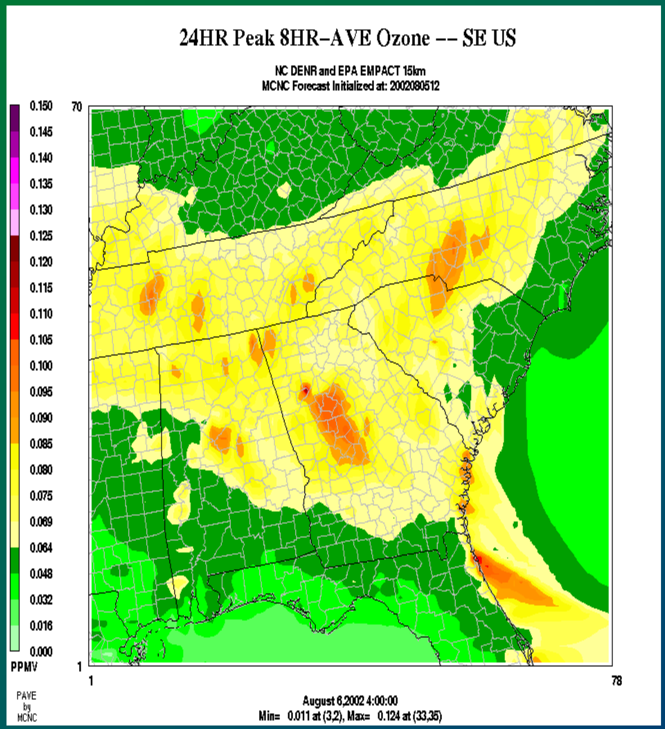
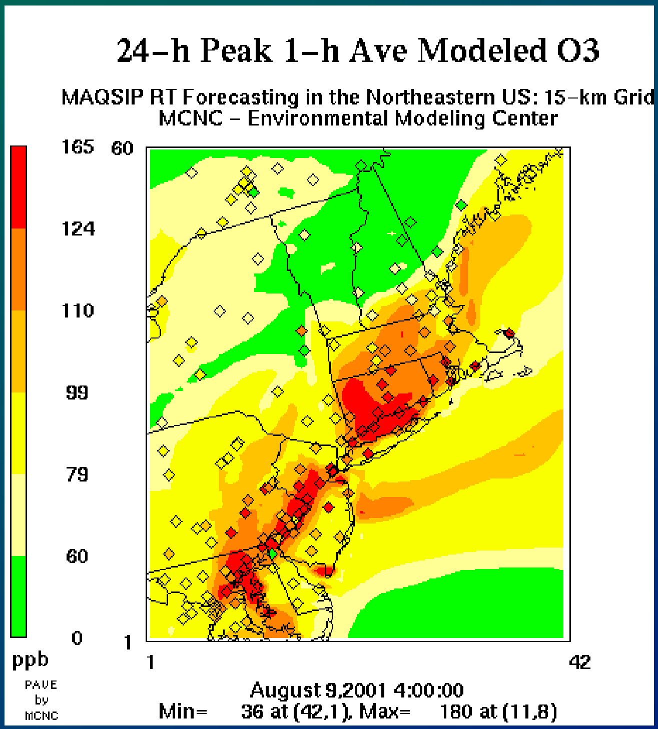
Introduction and Background 4

Typical Output Guidance Products





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The three focus areas for this research are regional air quality, intercontinental transport, and radiation balance.

- 13 Aircraft
- 5 Countries

Funding by

National Oceanic and Atmospheric Administration (NOAA)
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Partners

NASA Ames Research Center
NASA Dryden Flight Research Center
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NOAA Aeronomy Laboratory
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NOAA Atlantic Oceanographic and Meteorological Laboratory
NOAA Climatic Monitoring and Diagnostic Laboratory
NOAA Environmental Technology Laboratory
NOAA Forecast Systems Laboratory
NOAA Geophysical Fluid Dynamics Laboratory
NOAA National Geophysical Data Center
NOAA Pacific Marine Environmental Laboratory
DOE Argonne National Laboratory
DOE Brookhaven National Laboratory
DOE Pacific Northwest National Laboratory
DLR-Aircraft Operation Department
DLR-Institute for Atmospheric Physics
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Woods Hole Oceanographic Institution

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Modeling Study

Forecast Models Used in ICARTT-2K4 Ensemble	Provided By
Multiscale Air Quality Simulation Platform – Real-Time **(MAQSIP-RT 45km)**	*Baron Advanced Meteorological Systems*
Multiscale Air Quality Simulation Platform – Real-Time **(MAQSIP-RT 15km)**	*Baron Advanced Meteorological Systems*
Eta-Community Model for Air Quality **(Eta-CMAQ 12km)**	*NOAA/NWS National Centers for Environmental Prediction*
Weather Research and Forecast Model – Chemistry **(WRF-Chem 27km)**	*NOAA Forecast Systems Laboratory*
Canadian Hemispheric and Regional Ozone and NOx System **(CHRONOS 21km)**	*Canadian Meteorological Service*
A Unified Regional Air-Quality Modeling System **(AURAMS 42km)**	*Canadian Meteorological Service*
Sulfur Transport and Emission Model 2003 **(STEM – 2K3 12km)**	*University of Iowa*

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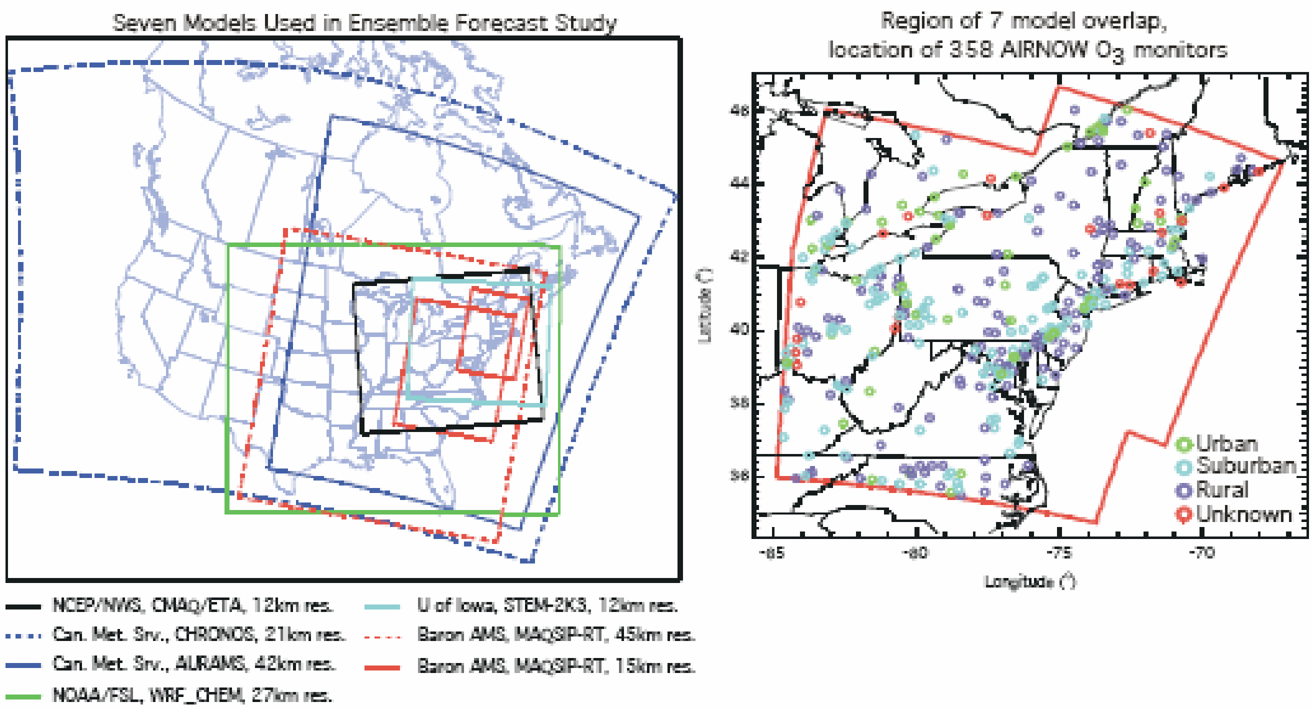
The 56 day period between 00Z 7/6/04 and 00Z 8/30/04 is the sampling period used in this analysis.

Figure 1



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MAQSIP-RT Results in Context of Seven Member Ensemble

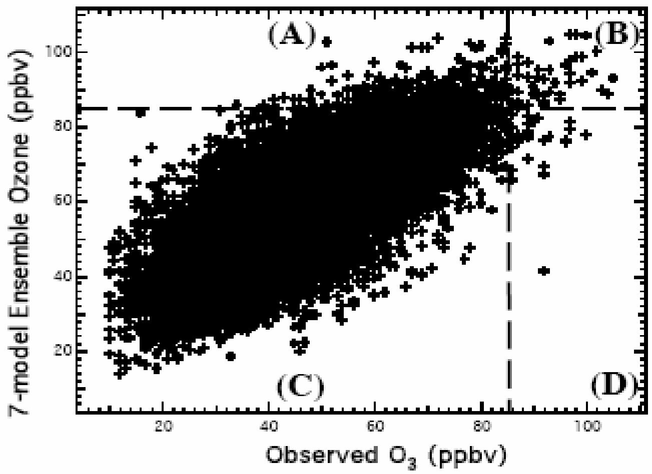
$$r(i) = \frac{\sum_{days}\left(O_3^{model}(i,day) - O_3^{model}(i,avg)\right)\left(O_3^{obs}(i,day) - O_3^{obs}(i,avg)\right)}{\sqrt{\sum_{days}\left(O_3^{model}(i,day) - O_3^{model}(i,avg)\right)^2 \sum_{days}\left(O_3^{obs}(i,day) - O_3^{obs}(i,avg)\right)^2}} \quad (1),$$

the mean bias;

$$\text{Mean Bias}(i) = \left(\frac{1.}{N_{days}}\right)\sum_{days}\left[O_3^{model}(i,day) - O_3^{obs}(i,day)\right] \quad (2),$$

and the root mean square error;

$$\text{RMSE}(i) = \sqrt{\left(\frac{1.}{N_{days}}\right)\sum_{days}\left(O_3^{model}(i,day) - O_3^{obs}(i,day)\right)^2} \quad (3),$$

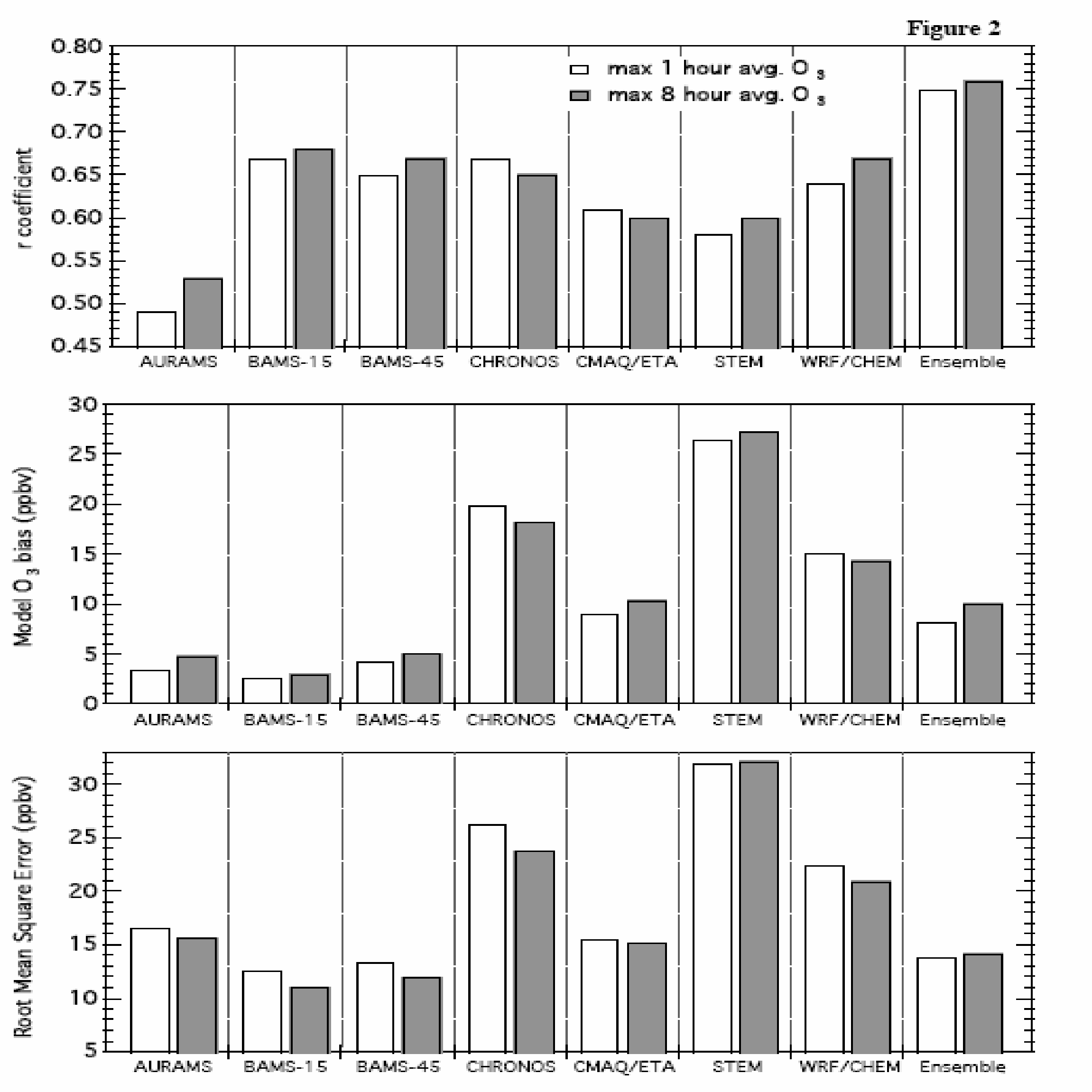


Probability of Detection: $\frac{B}{B+D}$

False Alarm Rate: $\frac{A}{B+A}$

Critical Success Index: $\frac{B}{B+A+D}$

Bias Ratio: $\frac{A+B}{B+D}$



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MAQSIP-RT Results in Context of Seven Member Ensemble

	median	average
r coeff.	0.67	0.63
Bias	4.57	5.10
RMSE	11.74	12.40

Categorical Evaluation

Accuracy (%)	99.06
Prob. of Detection (%)	21.52
False Alarm Rate (%)	79.01
Crit. Success Index (%)	11.89
Bias (ratio)	1.03

Peak 8-hr stats

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MAQSIP-RT Results in Context of Seven Member Ensemble

BAMS 45km

Comparison Statistics for
BAMS (45km) with
AIRNOW daily 8-hr max O_3
7/6/04 through 8/25/04

	median	average
r coeff.	0.67	0.63
Bias	4.57	5.10
RMSE	11.74	12.40

Categorical Evaluation
Accuracy (%) 99.06
Prob. of Detection (%) 21.52
False Alarm Rate (%) 79.01
Crit. Success Index (%) 11.89
Bias (ratio) 1.03

WRF-C 27km

Comparison Statistics for
WRF-1 (27km) with
AIRNOW daily 8-hr max O_3
7/6/04 through 8/25/04

	median	average
r coeff.	0.68	0.65
Bias	14.07	13.79
RMSE	20.75	20.88

Categorical Evaluation
Accuracy (%) 84.41
Prob. of Detection (%) 86.08
False Alarm Rate (%) 96.84
Crit. Success Index (%) 3.14
Bias (ratio) 27.25

Eta-CMAQ 12km

Comparison Statistics for
CMAQ/ETA (12km) with
AIRNOW daily 8-hr max O_3
7/6/04 through 8/25/04

	median	average
r coeff.	0.58	0.56
Bias	9.95	9.76
RMSE	14.87	15.31

Categorical Evaluation
Accuracy (%) 98.33
Prob. of Detection (%) 49.37
False Alarm Rate (%) 82.51
Crit. Success Index (%) 14.83
Bias (ratio) 2.82

CHRONOS 21km

Comparison Statistics for
CHRONOS (21km) with
AIRNOW daily 8-hr max O_3
7/6/04 through 8/25/04

	median	average
r coeff.	0.66	0.63
Bias	17.91	17.80
RMSE	23.51	23.76

Categorical Evaluation
Accuracy (%) 81.50
Prob. of Detection (%) 75.95
False Alarm Rate (%) 97.63
Crit. Success Index (%) 2.36
Bias (ratio) 32.00

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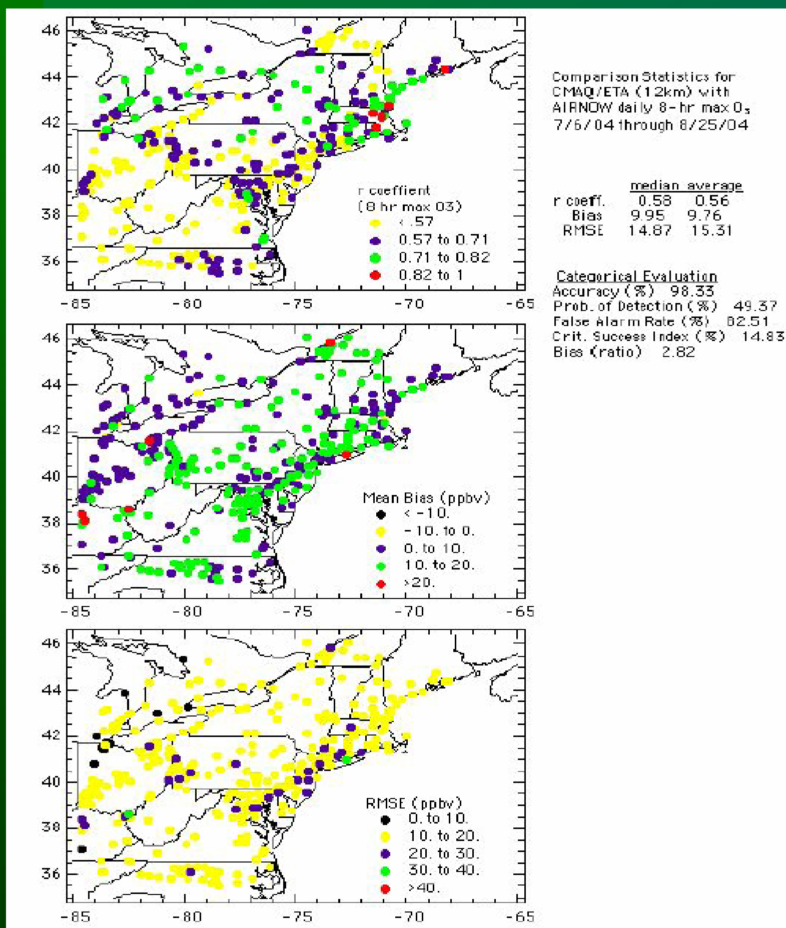
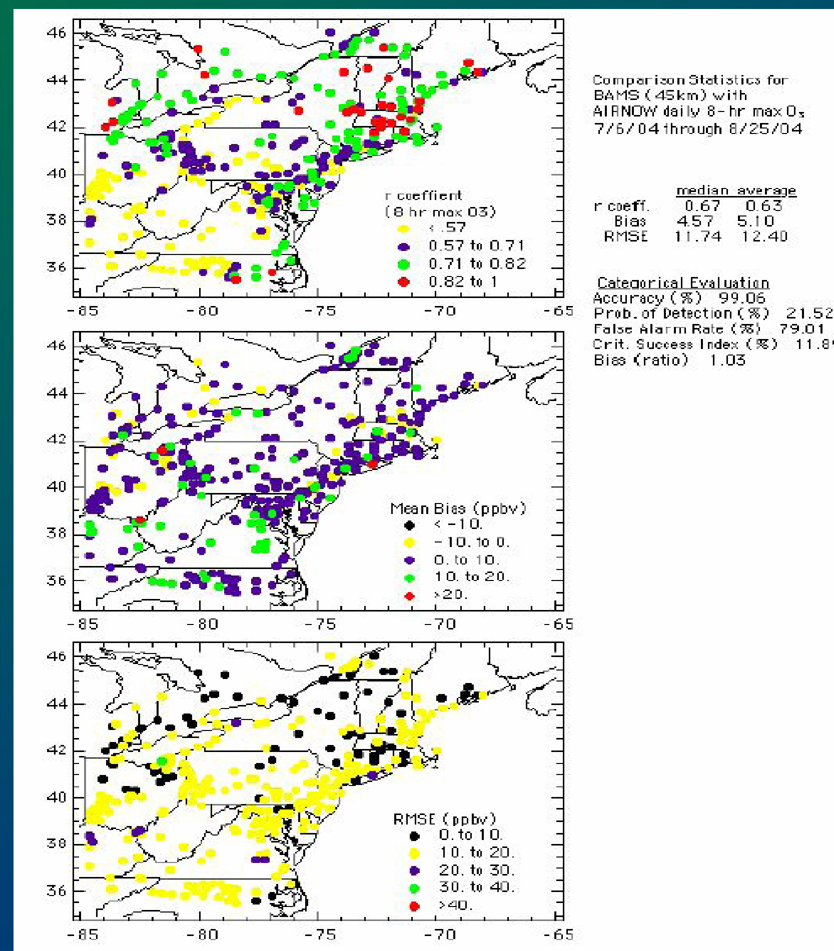
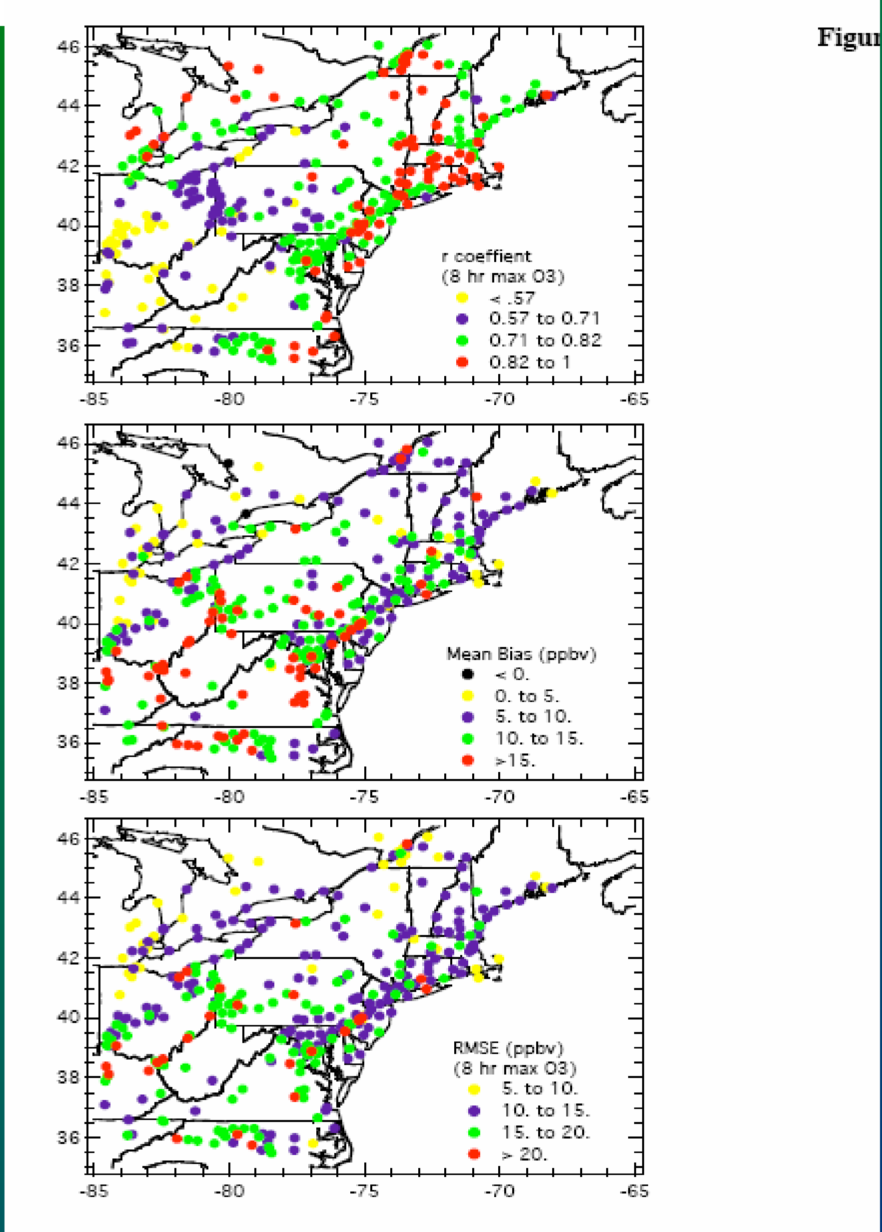
MAQSIP-RT Results in Context of Seven Member Ensemble







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MAQSIP-RT Results in Context of Seven Member Ensemble

Seven Member Ensemble Result

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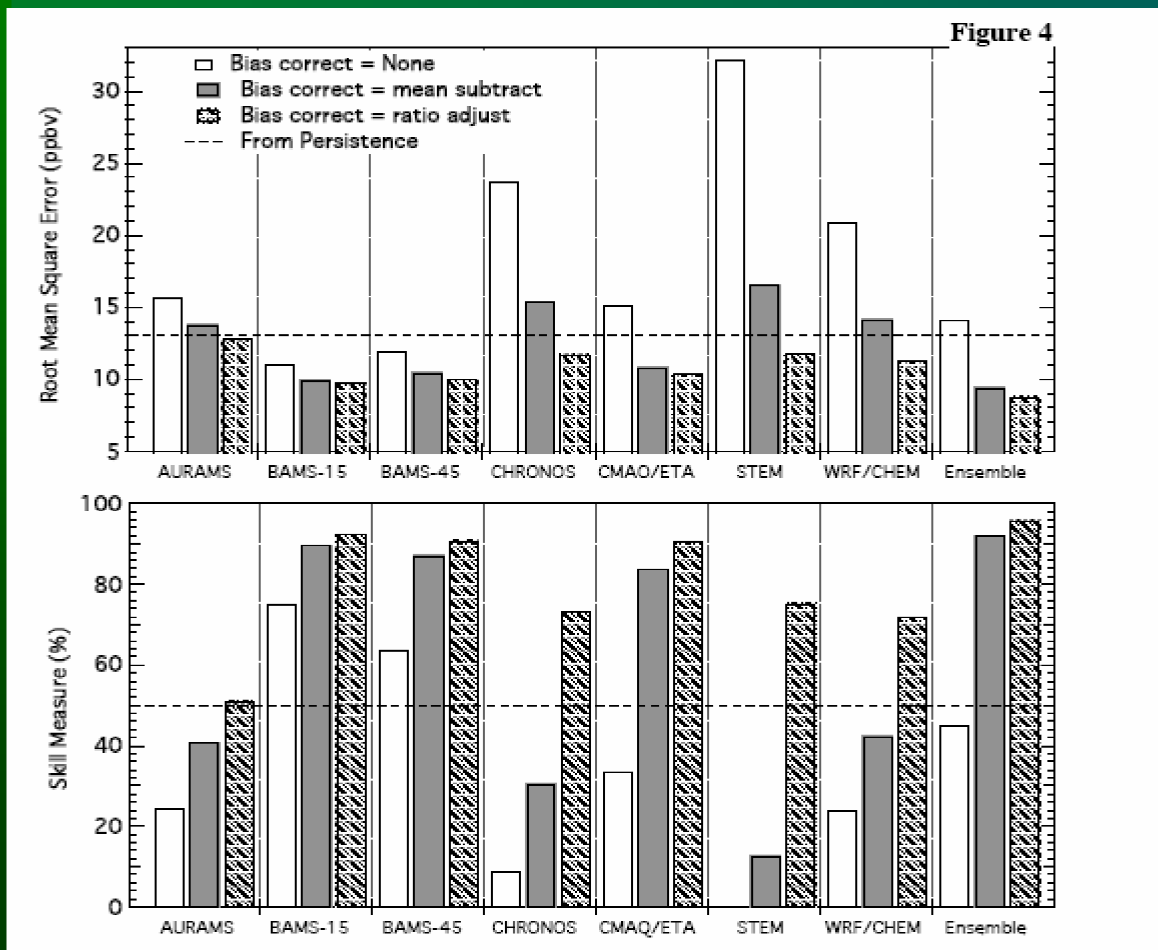


Fraction of model-to-measurement comparisons that have lower rmse scores when compared to persistence Is used as a measure of skill

Models having 50% or more points with lower rmse when compared with persistence are considered to have some skill

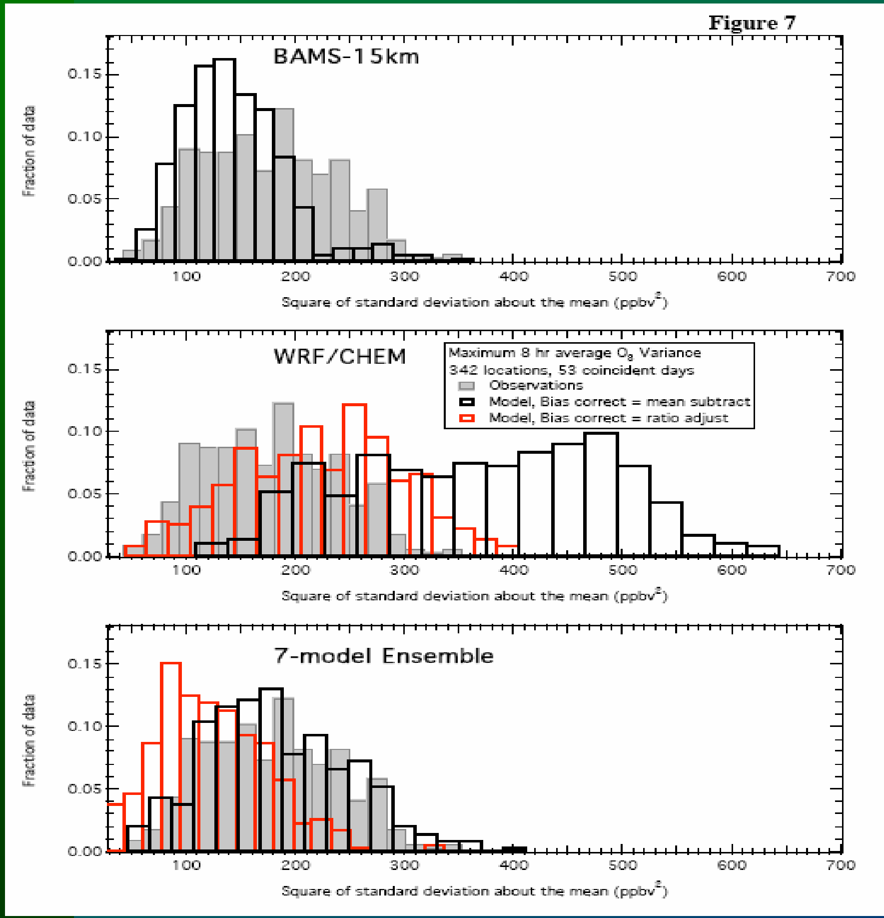
BIAS Correction improves skill in all cases: however, without bias correction, even the ensemble has poorer skill than the BAMS models

We define the *variance* at a given monitor to be the square of the standard deviation about the average O_3:

$$\text{Variance(i)} = \left(\frac{1.}{N_{days}}\right)\sum_{days}\left(O_3(i,day) - O_3(i,average)\right)^2 \quad (6),$$

where O_3 can either be observed or model daily maximum average O_3. This quantity is chosen because it represents the power of the O_3 signal about the mean from a purely signal processing point of view.

where i refers to O_3 monitor i (i=1 to 342), N_{days} refers to number of observing days at each site,



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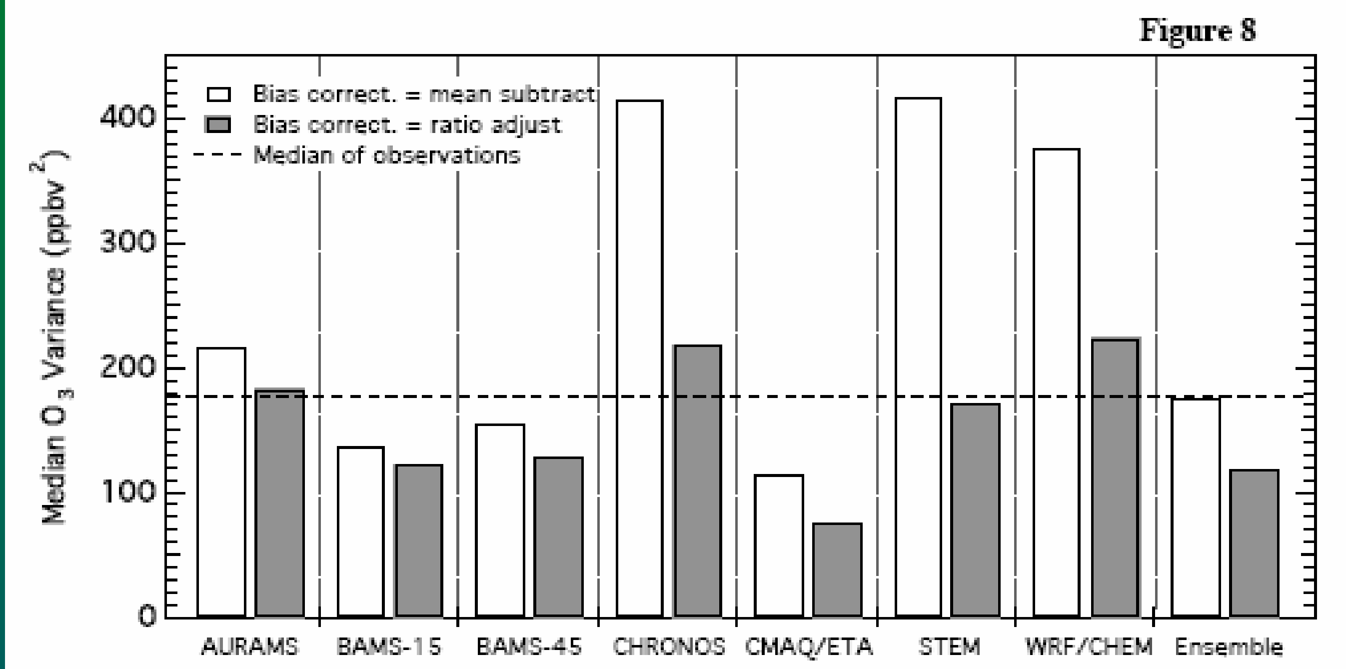
MAQSIP-RT Results in Context of Seven Member Ensemble

MAQSIP-RT Results in Context of Seven Member Ensemble



Study Conclusions: Individual Models and Ensembles

Combined Error Statistic Comparison – No Bias Correction

CES = (RMSE + BIAS)/(Corr) ***A score of 0 is "perfect"***

Forecast Models Used During ICARTT – 2K4	**Combined Error Statistic**
Multiscale Air Quality Simulation Platform – Real-Time (**MAQSIP-RT 45km)**	22.15
Multiscale Air Quality Simulation Platform – Real-Time (**MAQSIP-RT 15km)**	27.77
NOAA-EPA (**Eta-CMAQ Community Model for Air Quality 12km)**	44.76
Weather Research and Forecast Model – Chemistry (**WRF-Chem 27km)**	53.33
Canadian Hemispheric and Regional Ozone and Nox System (**CHRONOS 21km)**	65.96
A Unified Regional Air-Quality Modeling Systems (**AURAMS 42km)**	44.70
Sulfur Transport and Emissions Model (**STEM –2K3 12km)**	108.92
Ensemble	34.92

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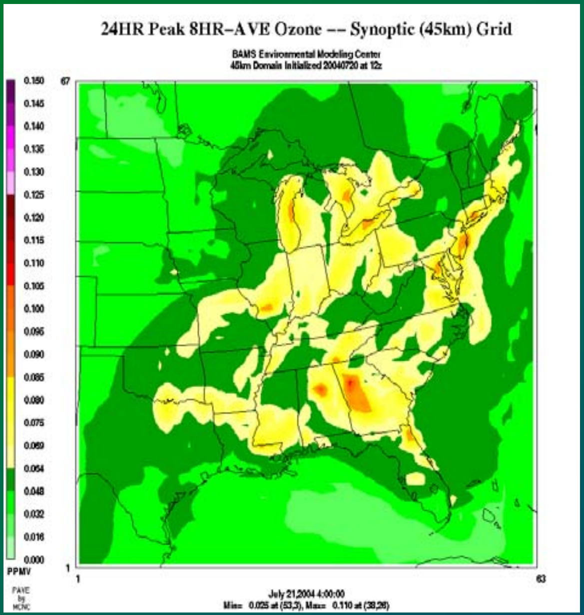

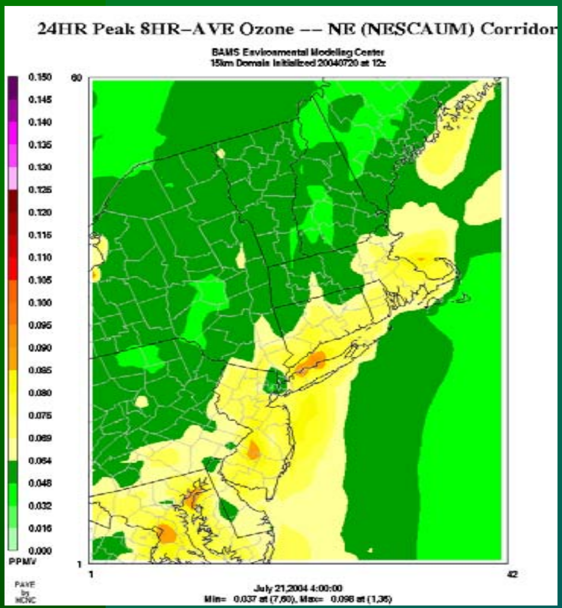

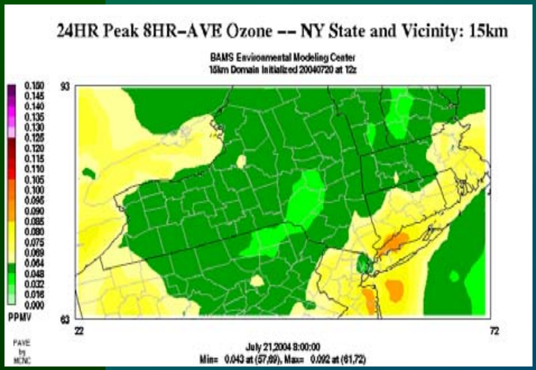

Figures 1a, b, and c (top, middle, and bottom). MAQSIP-RT 45km (top) and different 15km (middle and bottom) forecasts for peak 8-hr ozone valid July 21, 2004 issued 12z July 20, 2004.

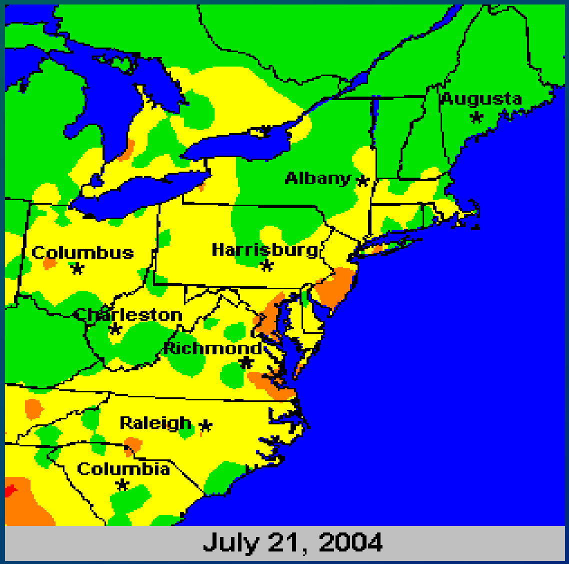

Figure 2. *AIRNow gridded peak 8-hour ozone observations for July 21, 2004.*

MAQSIP-RT Results in Context of Seven Member Ensemble

Study Conclusions: Individual Models and Ensembles

- *The BAMS MAQSIP-RT systems leads all models available in the US and Canada in forecast skill*

- *Ensembles of forecast models have promise to improve skill even further over single model forecasts*

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Baron Advanced: Where are we Going?

We will be introducing CONUS forecasts not only for ozone but for PM 2.5 and HAZE this coming forecast season

We will be offering an ensemble air quality forecast product suite in the near future

We will continue to contribute to the national AQF effort through participation in field intensives and other R&D opportunities

STOP BY OUR BOOTH FOR MORE DETAILS!!!

And be sure to see Carlie Coats' poster with details of our Eta-CMAQ enabling technology

Reference and Contact Information

- **McKeen, S., J. Wilczak, G. Grell, I. Djalalova, S. Peckham, E.-Y. Hsie, W. Gong, V. Bouchet, S. Menard, R. Moffet, J. McHenry, J. McQueen, Y. Tang, G.R. Carmichael, M. Pagowski, A. Chan, and T. Dye, 2005: Assessment of an ensemble of seven real-time ozone forecasts over Eastern North America during the summer of 2004. *Submitted to Atmospheric Environment.***

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